Snowmass 2021 Energy Frontier

Kick-Off Meeting, May 21 2020

Meenakshi Narain (Brown U.)
Laura Reina (FSU)
Alessandro Tricoli (BNL)

The Snowmass process

Long-term planning exercise for the particle-physics community.

- "Develop community long-term physics aspirations."
- "Communicate opportunities for discovery in particle-physics to broader community and to the (US) government."

(Young-Kee Kim, DPF Chair, Town-Hall Meeting, 2020 April APS meeting)

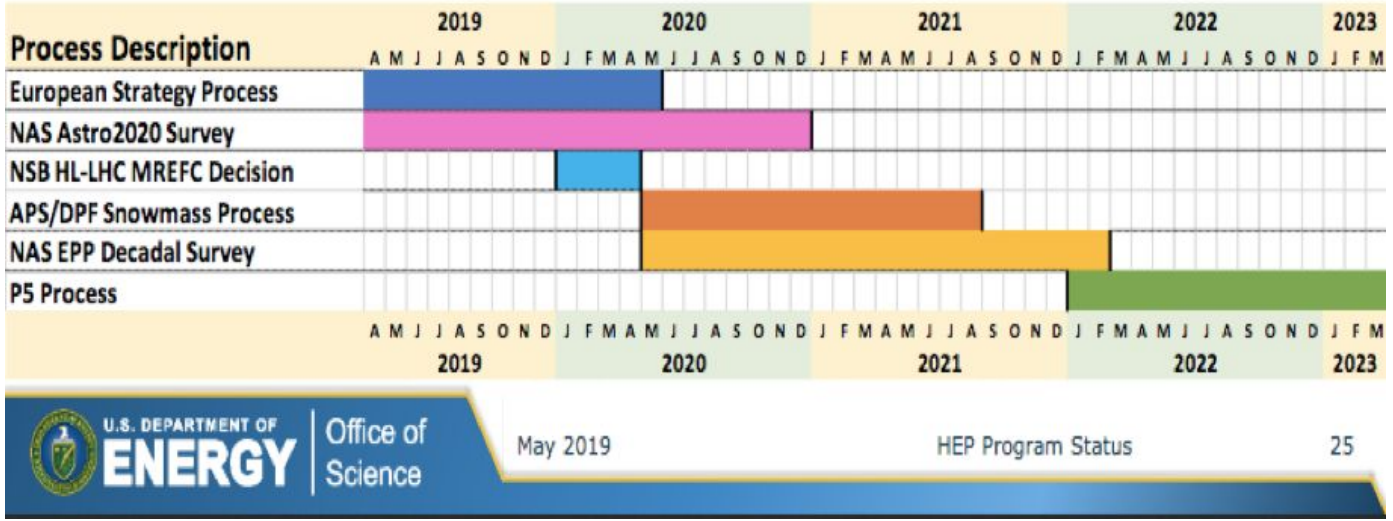
Physics-driven effort.

- Covers all areas of particle physics and facilitates cross-cutting.
- Develop overarching physics studies.

Global effort.

- Input from non-US community is essential.
- Input from recent international studies, for example HL-LHC, European Strategy Particle Physics Update (ESPPU), future colliders etc.

International Timeline



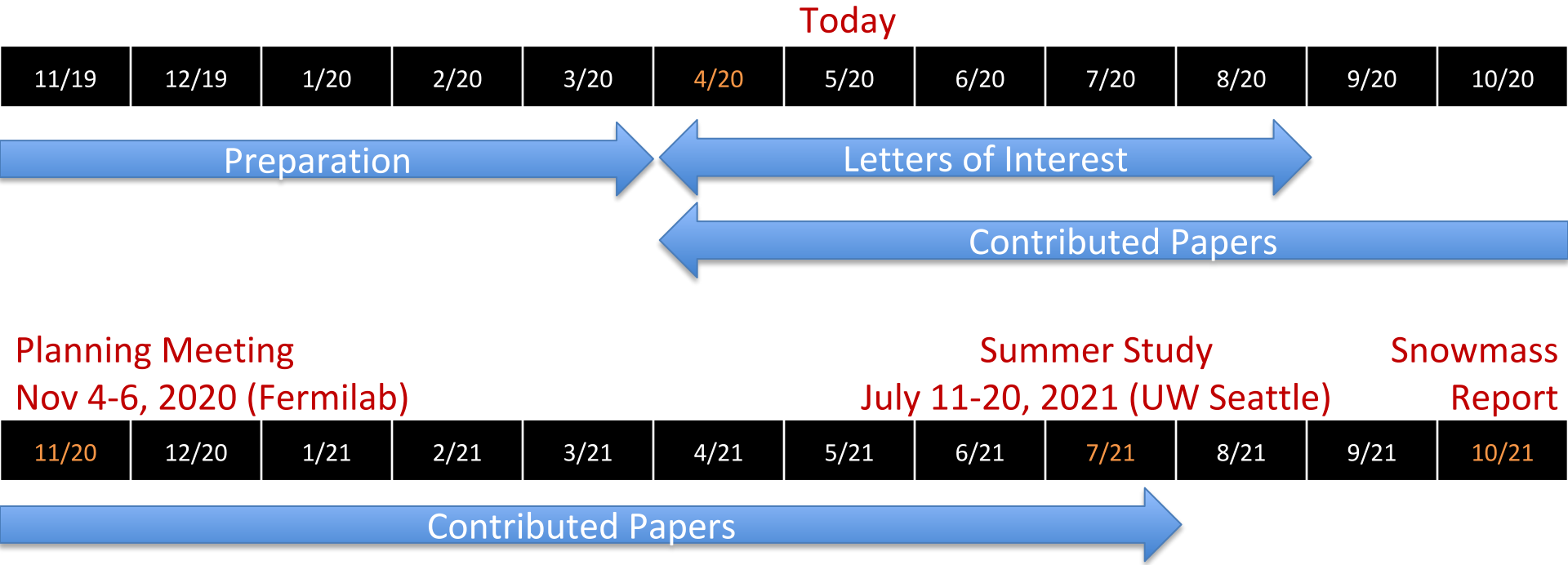
Snowmass Final Report: Fall 2021

NAS (National Academy of Sciences) Decadal Survey Report: end 2020 or very early 2022

Snowmass 2021 results will be used as input to the next P5 (2022)

Snowmass 2021 Timeline

We are ahead of the curve compared to Snowmass 2013



Past Snowmass and P5

- **Snowmass 2013**: **new successful model**
  - Energy Frontier
  - Intensity Frontier
  - Cosmic Frontier
  - Cross-cutting groups: Facilities, Instrumentation, Computing, Theory, Communication.

  Report: https://www.slac.stanford.edu/econf/C1307292/

- **P5 (2014)**: identified **five scientific drivers**
  - Use the Higgs boson as a new tool for discovery.
  - Pursue the physics associated with neutrino masses.
  - Identify the new physics of dark matter.
  - Understand cosmic acceleration: dark energy and inflation.
  - Explore the unknown: new particles, interaction, and physical principles.

  Report: https://www.usparticlephysics.org

P5 2014 has been very successful !!

Scientific Drivers

The Unknown (U.S.)

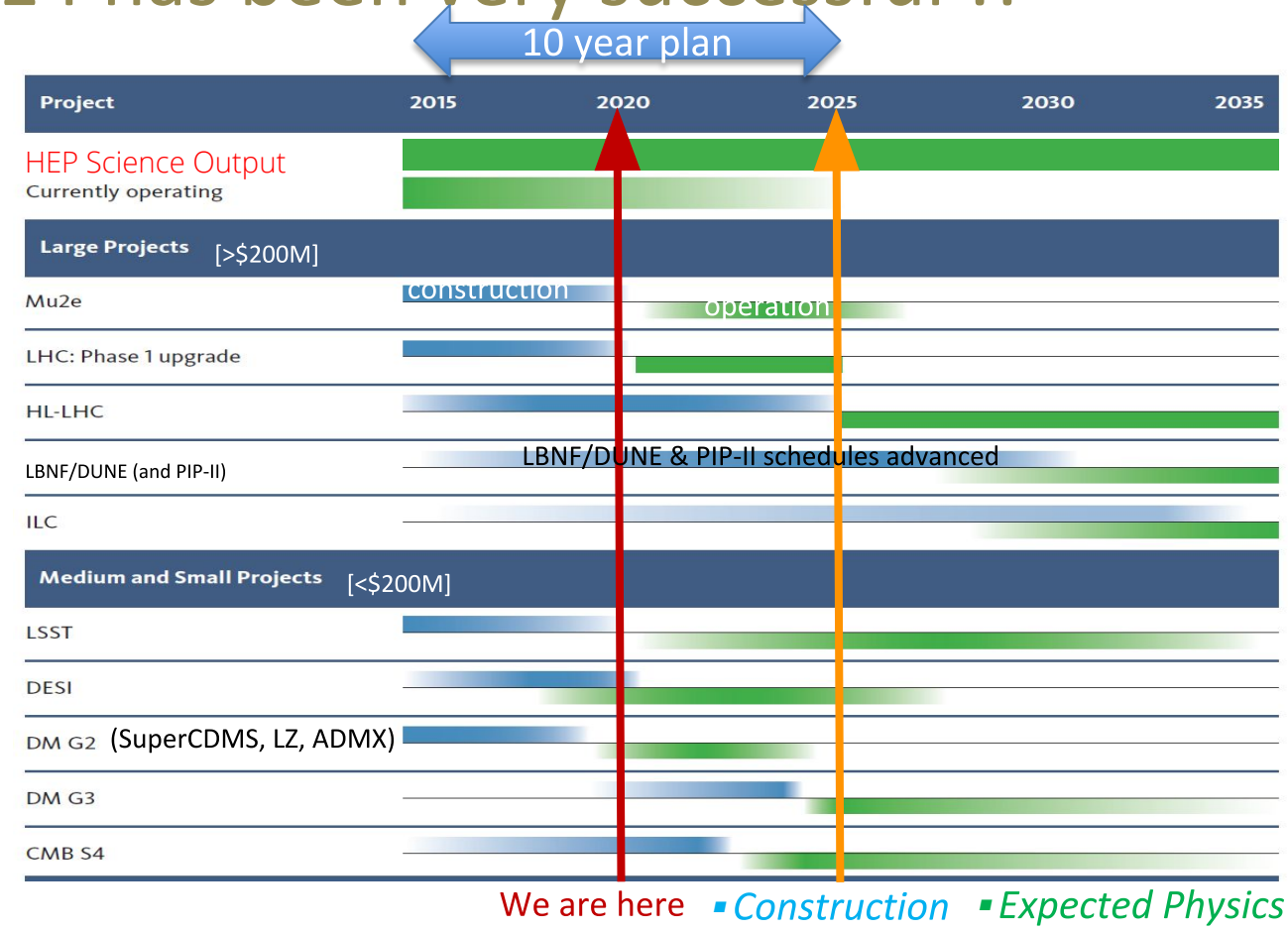
Higgs as a tool (Europe)
The Unknown

Neutrino (U.S.)

Cosmic Acceleration (U.S.)

Dark Matter (U.S.)

Cosmic Acceleration (U.S.)

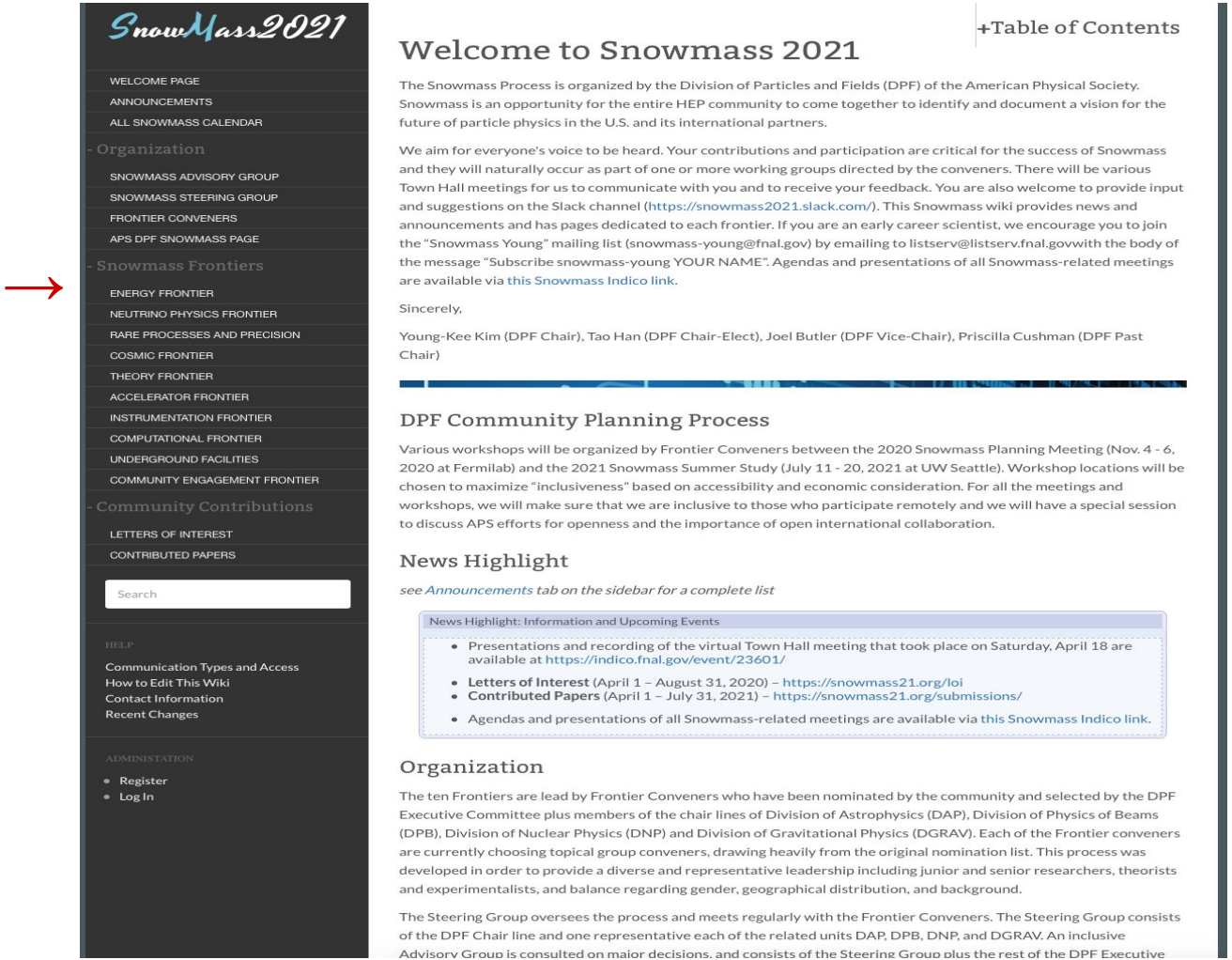


Snowmass 2021: leading to the next P5

Ten Frontiers (with Liaisons inbetween).

- **Energy Frontier**
- Frontiers in Neutrino Physics
- Rare Processes & Precision Measurements
- Cosmic Frontier
- Theory Frontier
- Underground Facilities
- Accelerator Frontier
- Instrumentation Frontier
- Computational Frontier
- Community Engagement Frontier

Wiki: https://snowmass21.org/start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Welcome to Snowmass 2021
The Snowmass Process is organized by the Division of Particles and Fields (DPF) of the American Physical Society. Snowmass is an opportunity for the entire HEP community to come together to identify and document a vision for the future of particle physics in the U.S. and its international partners.
We aim for everyone's voice to be heard. Your contributions and participation are critical for the success of Snowmass and they will naturally occur as part of one or more working groups directed by the conveners. There will be various Town Hall meetings for us to communicate with you and to receive your feedback. You are also welcome to provide input and suggestions on the Slack channel (https://snowmass2021.slack.com/). This Snowmass wiki provides news and announcements and has pages dedicated to each frontier. If you are an early career scientist, we encourage you to join the "Snowmass Young" mailing list (snowmass-young@fnal.gov) by emailing to listserv@listserv.fnal.govwith the body of the message "Subscribe snowmass-young YOUR NAME". Agendas and presentations of all Snowmass-related meetings are available via this Snowmass Indico link.
Sincerely,
Young-Kee Kim (DPF Chair), Tao Han (DPF Chair-Elect), Joel Butler (DPF Vice-Chair), Priscilla Cushman (DPF Past Chair)
DPF Community Planning Process
Various workshops will be organized by Frontier Conveners between the 2020 Snowmass Planning Meeting (Nov. 4 - 6, 2020 at Fermilab) and the 2021 Snowmass Summer Study (July 11 - 20, 2021 at UW Seattle). Workshop locations will be chosen to maximize "inclusiveness" based on accessibility and economic consideration. For all the meetings and workshops, we will make sure that we are inclusive to those who participate remotely and we will have a special session to discuss APS efforts for openness and the importance of open international collaboration.
News Highlight
see Announcements tab on the sidebar for a complete list
News Highlight: Information and Upcoming Events
Presentations and recording of the virtual Town Hall meeting that took place on Saturday, April 18 are available at https://indico.fnal.gov/event/23601/
Letters of Interest (April 1 – August 31, 2020) – https://snowmass21.org/loi
Contributed Papers (April 1 – July 31, 2021) – https://snowmass21.org/submissions/
Agendas and presentations of all Snowmass-related meetings are available via this Snowmass Indico link.
Organization
The ten Frontiers are lead by Frontier Conveners who have been nominated by the community and selected by the DPF Executive Committee plus members of the chair lines of Division of Astrophysics (DAP), Division of Physics of Beams (DPB), Division of Nuclear Physics (DNP) and Division of Gravitational Physics (DGRAV). Each of the Frontier conveners are currently choosing topical group conveners, drawing heavily from the original nomination list. This process was developed in order to provide a diverse and representative leadership including junior and senior researchers, theorists and experimentalists, and balance regarding gender, geographical distribution, and background.
The Steering Group oversees the process and meets regularly with the Frontier Conveners. The Steering Group consists of the DPF Chair line and one representative each of the related units DAP, DPB, DNP, and DGRAV. An inclusive Advisory Group is consulted on major decisions, and consists of the Steering Group plus the rest of the DPF Executive

Introducing the Energy Frontier

Conveners:

wiki: https://snowmass21.org/energy/start

The Energy Frontier (EF) group will explore the TeV energy scale and beyond. Our sharply focused agenda includes understanding the heaviest particles of the Standard Model (SM), as well as exploring physics beyond the SM to discover new particles and interactions, including unraveling the mystery of dark matter. In this context, the EF group will carry out (and compile) detailed studies of **Electroweak (EW) physics, QCD and strong interactions, and Beyond-Standard-Model (BSM) physics** under different future accelerator scenarios, including lepton-lepton, hadron-hadron, and lepton-hadron colliders.

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ENERGY FRONTIER

Frontier Conveners

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Description

The Energy Frontier (EF) group will explore the TeV energy scale and beyond. Our sharply focussed agenda includes understanding the heaviest particles of the Standard Model (SM), as well as exploring physics beyond the SM to discover new particles and interactions, including unraveling the mystery of dark matter. In this context, the EF group will carry out (and compile) detailed studies of **Electroweak (EW) physics, QCD and strong interactions, and Beyond-Standard-Model (BSM) physics** under different future accelerator scenarios, including lepton-lepton, hadron-hadron, and lepton-hadron colliders.

In more detail, the EF group will investigate the reach and future prospects of **EW physics, with emphasis on the Higgs sector**, such as Higgs-boson properties and couplings, Higgs boson as a portal to new physics, as well as Standard Model gauge-bosons scattering and production, and how they can be fed into precision EW fits to constrain new physics in a more model-independent way. As part of the EF portfolio, there will be studies of top-, bottom-, and charm-quark production. The impact of higher-order EW corrections in high-energy collisions will be an overarching theme that will cut across all precision studies.

In the context of **QCD physics,** the EF group will study how cutting-edge developments in higher-order perturbative QCD calculations and jet structure description can enhance precision physics and the reach for new physics at high-energy colliders, with particular emphasis on future scenarios. In addition, prospect measurements of the strong coupling constant and its running, as well as quark masses will be tackled. As in previous hadron colliders, we expect that several precision QCD measurements, e.g. W/Z(+jets), will be used in future hadron colliders as inputs to global PDF fits. Monte Carlo event generators will be very important in any future collider and we expect developments in the event generations, in terms of higher orders in QCD and EW calculations as well as in the computational techniques. In the QCD sector, we will also study hadronic structures, hadron spectroscopy, and forward QCD physics. We expect that results from lattice QCD calculations will provide valuable inputs in several QCD studies. In parallel, we will study prospects for heavy-ion physics at future colliders, with particular emphasis on the impact that this will have on the physics program of the EF.

Energy Frontier: exploring the TeV scale

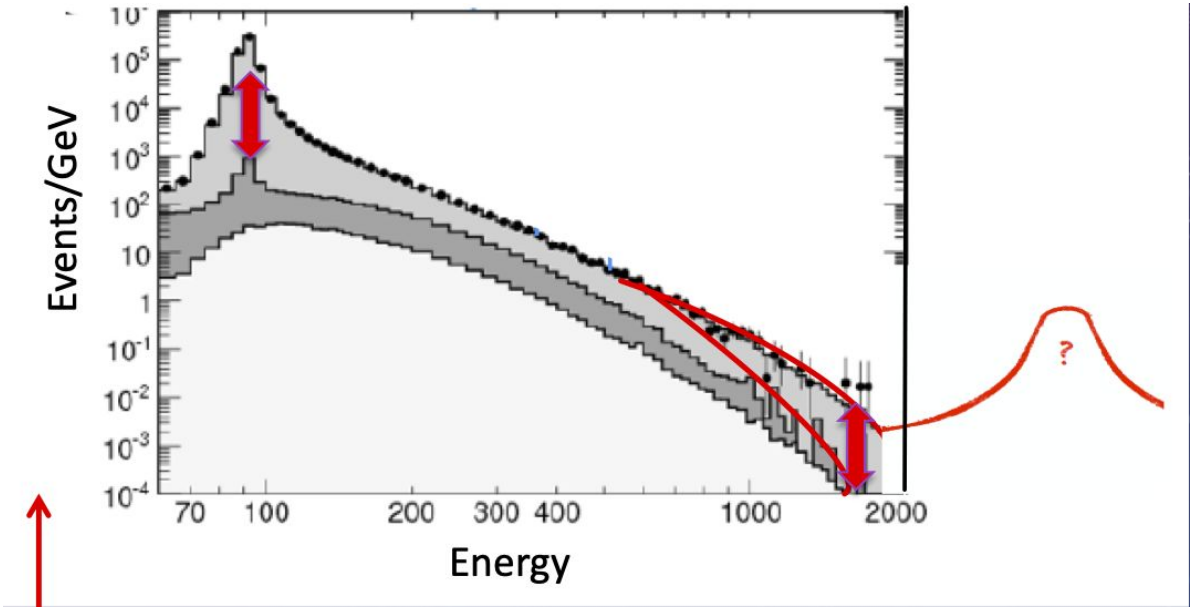
Snowmass 2013: in the wake of an amazing discovery

- Right after **LHC Run 1** and the **Higgs discovery**.
- Opening of a **new era of SM precision physics** and **BSM explorations**.

Moving forward, we need to consider:

- More luminosity → precision measurements
- Higher energy → extend reach of direct searches
- Improved theory predictions → affect both

Energy Frontier: exploring the TeV scale



(from F. Riva)

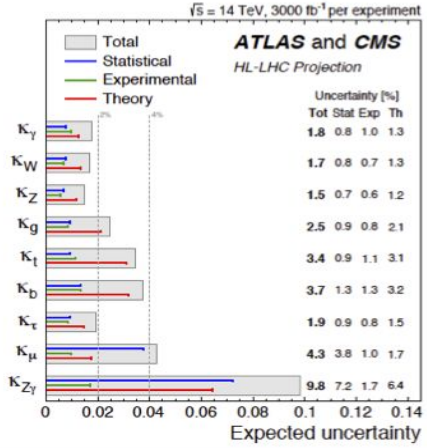
- Precision: indirect evidence of deviations at low and high energy.
- Energy: direct access to new resonances.

Energy Frontier: exploring the TeV scale

Stress-testing the Higgs sector

κ=(measured coupling)/(SM coupling)

	CMS	ATLAS
k_Z	$.99^{+.11}_{-.12}$	$1.10^{+.08}_{-.08}$
k_W	$1.10^{+.12}_{-.17}$	$1.05^{+.08}_{-.08}$
k_t	$1.11^{+.12}_{-.10}$	$1.02^{+.11}_{-.10}$
k_b	$-1.10^{+.33}_{-.23}$	$1.06^{+.19}_{--.18}$
k_τ	$1.01^{+.16}_{-.20}$	$1.07^{+.15}_{-.15}$
k_μ	$.79^{+.58}_{-.79}$	<1.51 at 95% cl



$\Delta\kappa \sim v^2/\Lambda^2 \rightarrow$ sensitive to scale of NP

Higher precision probes higher Λ

% uncertainties with 2 ab^{-1}

	ILC250	ILC500
κ_γ	1.1	1.0
κ_W	1.8	0.4
κ_Z	.38	0.3
κ_g	2.2	0.97
κ_b	1.8	0.60
κ_τ	1.9	0.80

CLIC, % uncertainties

	350 GeV, 1 ab^{-1}	3 TeV, 5 ab^{-1}
κ_γ	-	2.3
κ_W	0.8	0.1
κ_Z	0.4	0.2
κ_g	2.1	0.9
κ_b	1.3	0.2
κ_τ	2.7	0.9

Energy Frontier: exploring the TeV scale

Difficult measurement: Higgs self-coupling ↔ EWSB

Collider	Accuracy on κ_λ	Running Years
HL-LHC	50%	12
HE-LHC	10-20%	20
ILC(500)	27%	21
CLIC(1500)	36%	15
CLIC(3000)	+11%, -7%	23
FCC(hh)	5%	13

Double vs single H production?

Indirect measurement?

Other options?

Deviations can be more subtle: not just a rescaling → explore effective interactions

Is that it? Are there more scalars? → direct searches

We still know very little, but we have very powerful constraints to guide us.

Energy Frontier: exploring the TeV scale

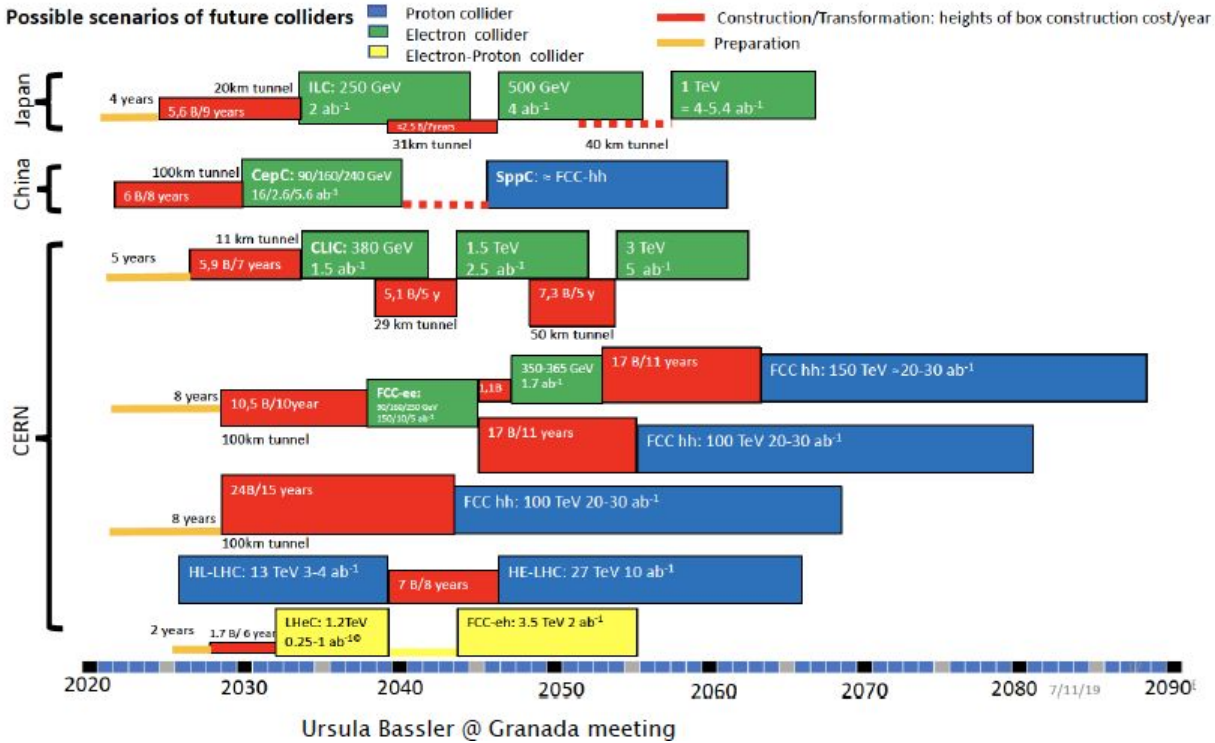
Snowmass 2021: a very exciting time

- LHC **Run 2** is providing a wealth of new measurements.
- Entering the era of **precision Higgs physics**.
- The **HL-LHC is a reality**.
- **Updated scenario of proposed future colliders**.
- Exciting results from other frontiers: rare processes, cosmology, …

AND we have no preferred way beyond the SM:

Great time to **propose new ideas, new perspectives, new tools**.

Future Collider Scenarios & Timelines



- Will add **EIC** and **Muon Collider** to this chart.
- Will consider **new proposals** that may come up during Snowmass 2021.
  - e.g. initiatives for gamma-gamma and plasma colliders etc.

Future Colliders Scenarios

- ESG studies, comparing various options, are detailed in the briefing book

- We will **expand on these studies** and **add other collider scenarios**, e.g. muon collider, Electron-Ion Collider, other c.o.m. (if needed)....

- Our goal is to:
  - Identify **"Focus Questions"** and the "**Scientific Merits"** of the various collider options.
  - Develop a global picture and a future roadmap.
  - Compile existing studies [start from ESG briefing book and confirm with Accelerator Frontier].
  - Add new studies and information.
  - For pp future colliders, HL-LHC will serve as a critical baseline. HL-LHC results may be revisited if deemed necessary.

Energy Frontier Topical Groups

Ten Topical Groups will study and compare the physics reach of future colliders.

Topical Group	Co-Conveners		
EF01: EW Physics: Higgs Boson properties and couplings	Sally Dawson (BNL)	Andrey Korytov (U Florida)	Caterina Vernieri (SLAC)
EF02: EW Physics: Higgs Boson as a portal to new physics	Patrick Meade (Stony Brook)	Isobel Ojalvo (Princeton)	
EF03: EW Physics: Heavy flavor and top quark physics	Reinhard Schwienhorst (MSU)	Doreen Wackeroth (Buffalo)	
EF04: EW Physics: EW Precision Physics and constraining new physics	Alberto Belloni (Maryland)	Ayres Freitas (Pittsburgh)	Junping Tian (Tokyo)
EF05: QCD and strong interactions: Precision QCD	Michael Begel (BNL)	Stefan Hoeche (FNAL)	Michael Schmitt (Northwestern)
EF06: QCD and strong interactions: Hadronic structure and forward QCD	Huey-Wen Lin (MSU)	Pavel Nadolsky (SMU)	Christophe Royon (Kansas)
EF07: QCD and strong interactions: Heavy Ions	Yen-Jie Lee (MIT)	Swagato Mukherjee (BNL)	
EF08: BSM: Model specific explorations	Jim Hirschauer (FNAL)	Elliot Lipeles (UPenn)	Nausheen Shah (Wayne State)
EF09: BSM: More general explorations	Tulika Bose (U Wisconsin-Madison)	Zhen Liu (Maryland)	Simone Griso (LBL)
EF10: BSM: Dark Matter at colliders	Caterina Doglioni (Lund)	LianTao Wang (Chicago)	

Identify Focus Questions and Ideas

Ideas for investigations that already emerged **in TG Kick-off Meetings**!

- What is the scale of New Physics that can be probed with precision measurement?
- Higgs “inverse problem”: what can we tell about BSM from Higgs couplings?
- How can theoretical precision match experimental precision? When is this necessary?
- Develop model-agnostic BSM physics using Machine Learning techniques.
- What is the value of new colliders? What is the motivation to do physics there?
- Explore new detectors and capabilities that enable new signatures.
- ...

It promises to be a very fruitful exercise!

Topical Group Activities

All EF Topical Groups (TG) have:

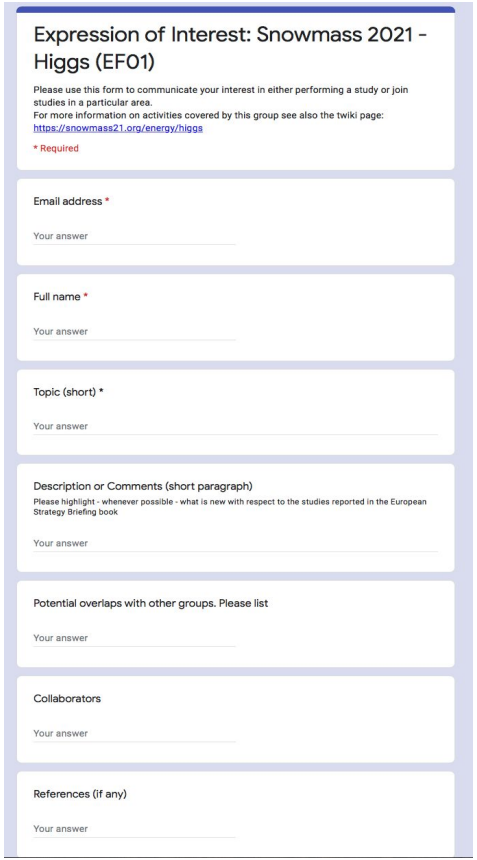
- wiki pages and Indico sites for their meetings
- **mailing lists** (subscribe!) and **Slack channels**.

Everybody's contribution and participation are vital to the Snowmass process!

How to engage:

- Contact the TG conveners and join the TG activities (join meetings, discussion).
- Bring existing studies and/or new ideas and projects to investigate.
- Fill in Expression of Interest forms prepared by TG (on-line).
- Write a Letter of Interest (LOI): 2 pages, briefly what you want to work on (the EF conveners and TG conveners will facilitate the process).
  - This can be done as individuals, user groups or collaborations
  - We invite collaborations & initiatives to submit (one or multiple) LOIs with a set of open questions and how to get new users involved in the studies.
- Various user groups are providing documents with contact informations, available studies, available tools, etc. (See Backup Slides for examples of what we have received so far).

TG Expression of Interest Forms



Expression of Interest: Snowmass 2021 - Higgs (EF01)

Please use this form to communicate your interest in either performing a study or join studies in a particular area.
For more information on activities covered by this group see also the twiki page:
https://snowmass21.org/energy/higgs

* Required

Email address *
Your answer

Full name *
Your answer

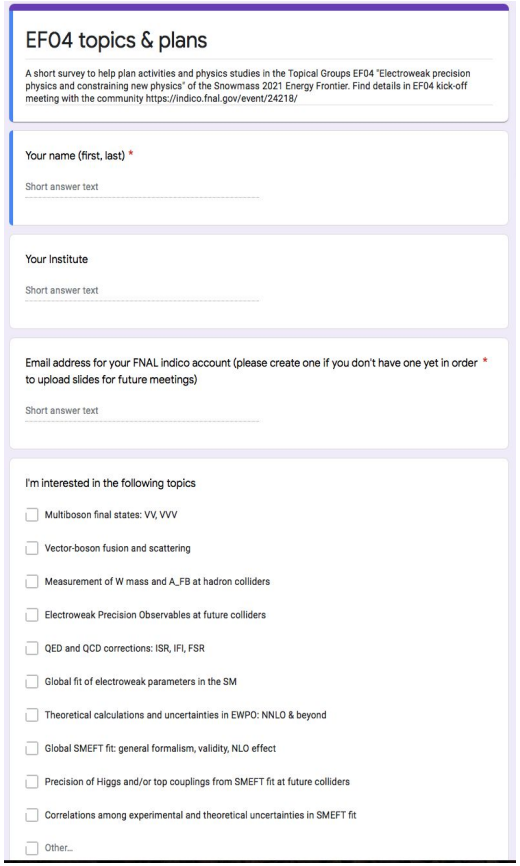
Topic (short) *
Your answer

Description or Comments (short paragraph)
Please highlight - whenever possible - what is new with respect to the studies reported in the European Strategy Briefing book
Your answer

Potential overlaps with other groups. Please list
Your answer

Collaborators
Your answer

References (if any)
Your answer



EF04 topics & plans

A short survey to help plan activities and physics studies in the Topical Groups EF04 "Electroweak precision physics and constraining new physics" of the Snowmass 2021 Energy Frontier. Find details in EF04 kick-off meeting with the community https://indico.fnal.gov/event/24218/

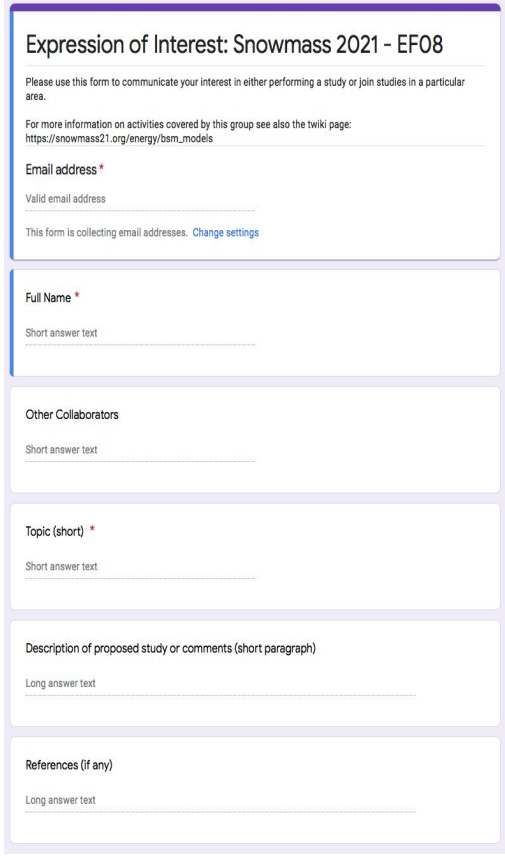
Your name (first, last) *
Short answer text

Your Institute
Short answer text

Email address for your FNAL indico account (please create one if you don't have one yet in order to upload slides for future meetings) *
Short answer text

I'm interested in the following topics

- Multiboson final states: VV, VVV
- Vector-boson fusion and scattering
- Measurement of W mass and A_FB at hadron colliders
- Electroweak Precision Observables at future colliders
- QED and QCD corrections: ISR, IFI, FSR
- Global fit of electroweak parameters in the SM
- Theoretical calculations and uncertainties in EWPO: NNLO & beyond
- Global SMEFT fit: general formalism, validity, NLO effect
- Precision of Higgs and/or top couplings from SMEFT fit at future colliders
- Correlations among experimental and theoretical uncertainties in SMEFT fit
- Other...



Expression of Interest: Snowmass 2021 - EF08

Please use this form to communicate your interest in either performing a study or join studies in a particular area.

For more information on activities covered by this group see also the twiki page:
https://snowmass21.org/energy/bsm_models

Email address *
Valid email address

This form is collecting email addresses. Change settings

Full Name *
Short answer text

Other Collaborators
Short answer text

Topic (short) *
Short answer text

Description of proposed study or comments (short paragraph)
Long answer text

References (if any)
Long answer text

More available online
(TG wiki pages)

EF: Engaging early career members of the community

The Snowmass process thrives on the participation of young people and offers an ideal environment for young people to get involved and promote their own initiatives.

We strongly encourage young members of the community to get involved!

To all senior members: get your students and postdocs involved!

Snowmass Young: forum of early career members.

- Nominations for representatives solicited (closes on May 22).
- Nominees: early career members (e.g. graduate students, postdocs).
- Coordinated by:
  - Sara M. Simons (2020 DPF Executive Committee Early Career Member)
  - Fernanda Psihas (2019 DPF Executive Committee Early Career Member)

Interaction among Topical Groups and Frontiers

- Many topics will be part of the physics program of several Topical Groups. We expect several joint activities, and joint session organized at EF meetings, starting with the July 9-10 EF General Meeting.

- Several studies will be joint with other Frontiers
  - Theory Frontier

    ↪ Planning meeting of all TG theory conveners (of all Frontiers)
  - Computational Frontier
  - Instrumentation Frontier
  - Accelerator Frontier

    ↪ We have received several requests, for example: "*The Accelerator Frontier ElectroWeak/Higgs Topical Group has been charged with showing how accelerators will do what is needed to advance physics. We will focus on performance, cost-mitigation, (especially for relatively mature technology), and will try to make sure alternative schemes receive adequate attention. Energy Frontier engagement is required for this and we would like to ask you to join us*"

and more ...

Liaisons among Frontiers

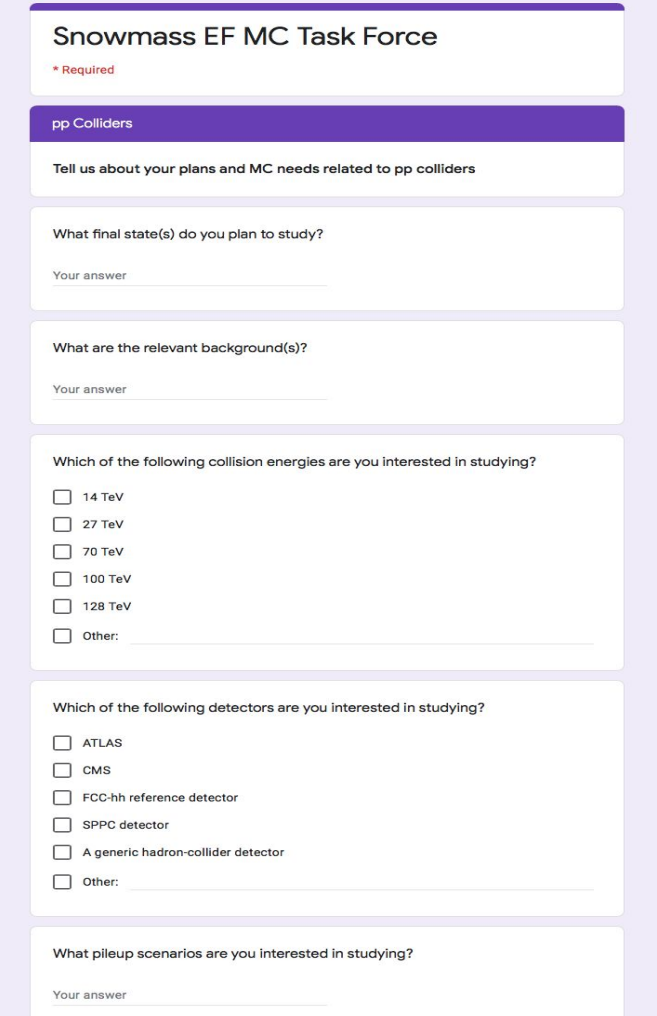
- They will provide high-level and bi-directional communication b/w Frontiers.
- They will be people with interests in both communities.
- **Official Liaisons:**
  - Neutrino Physics Frontier: André de Gouvêa (Northwestern)
  - Rare Processes and Precision: Angelo di Canto (BNL)
  - Cosmic Frontier: Caterina Doglioni (Lund)
  - Theory Frontier: Laura Reina (FSU)
  - Accelerator Frontier: Dmitri Denisov (BNL), Meenakshi Narain (Brown)
  - Computational Frontier: Daniel Elvira (FNAL)
  - Instrumentation Frontier: Caterina Vernieri (SLAC), Maksym Titov (Desy)
- In addition to official Liaison we foresee **unofficial 'Link People'**
  - Provide a more technical link between an EF-TG and a TG in other Frontiers.
  - We expect they will naturally emerge from the community by the November workshop.
  - They will be people who are embedded in both communities based on their personal interests.

Special Task: Monte Carlo samples production

- Since Snowmass 2013, the landscape for simulations for future colliders have changed.
  - Both future e+e- colliders (FCC-ee, CepC, ILC, CLIC etc) and pp colliders (FCC-hh, SppC) have developed simulation and analysis frameworks, and generated MC samples for their studies.
- Two-step strategy to address MC production for Snowmass 2021:
  - **Assess the MC needs** for EF (exp+th) and formulate a plan. We have formed a "**Task force**" for this purpose.
  - **Produce the "needed" MC samples** by the community to carry of the necessary studies for EF.

Special task: Monte Carlo Task Force

- Members of the EF MC task force: John Stupak (Chair)
  - EF TG conveners: Isobel Ojalvo, Michael Schmitt, Simon Pagan Griso.
  - MC authors: Fabio Maltoni, Stefan Hoeche.
  - OSG representative: Robert Gardner.
- In assessing the needs, the MC Task Force will:
  - Consider the process, the MC generators, the accelerator configurations, detector configurations, number of events.
  - Survey existing frameworks for MC generation and analysis for future colliders (FCC-ee, FCC-hh, CepC, SppC, LHeC, ILC, CLIC, Muon colliders, etc.)
  - Are they sufficient, are we permitted to use them?
  - Check if collaborations prefer users to use specific frameworks or a common one is agreeable
- The OSG has kindly agreed to support the MC generation for EF, and will provide both compute resources and storage on the OSG Data Federation
- Input to the MC Task Force will be facilitated by the TG conveners.



Snowmass EF MC Task Force

* Required

pp Colliders

Tell us about your plans and MC needs related to pp colliders

What final state(s) do you plan to study?

Your answer

What are the relevant background(s)?

Your answer

Which of the following collision energies are you interested in studying?

- [ ] 14 TeV
- [ ] 27 TeV
- [ ] 70 TeV
- [ ] 100 TeV
- [ ] 128 TeV
- [ ] Other:

Which of the following detectors are you interested in studying?

- [ ] ATLAS
- [ ] CMS
- [ ] FCC-hh reference detector
- [ ] SPPC detector
- [ ] A generic hadron-collider detector
- [ ] Other:

What pileup scenarios are you interested in studying?

Your answer

Google form to collect community input.

(preliminary, from John Stupak)

The idea is that:

Each topical group will use this as a starting point and adapt it appropriately for their groups, to ensure some uniformity across groups.

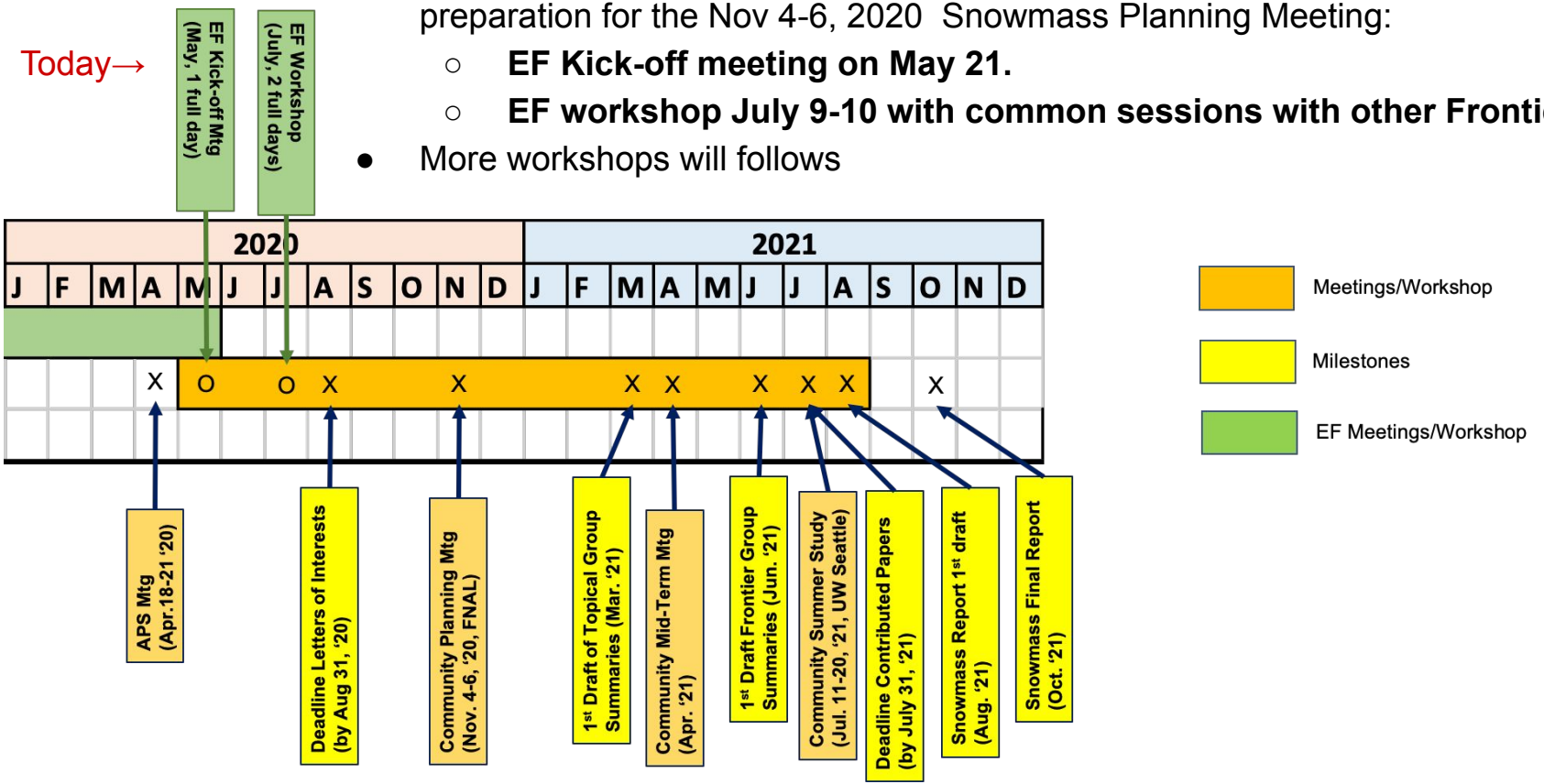
To be circulated soon...

Energy Frontier Planning

Next meeting ↘

Today→

- Two EF community meetings to be arranged before the LoI deadline and in preparation for the Nov 4-6, 2020 Snowmass Planning Meeting:
  - **EF Kick-off meeting on May 21.**
  - **EF workshop July 9-10 with common sessions with other Frontiers.**
- More workshops will follows

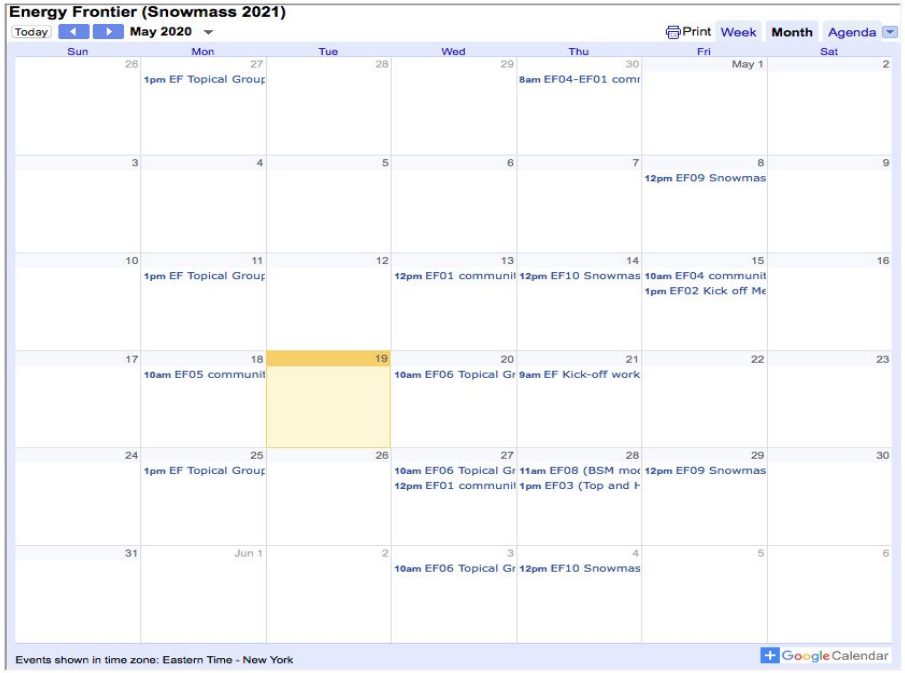


Today Meeting and July Workshop

- **Kick-off Meeting**: Today Thursday May 21, 2020 (full day).
  - Review of existing studies, and plans to engage communities.
    - *Goal is to lay out our plans, strategy, activities, discuss the organisation of the EF group and TGs, how to communicate within the community.*
    - *Summaries of studies that can be considered as stepping stones for TG activities (e.g. surveys of previous or international studies, e.g. ESG results, Yellow Reports etc.) as well as overviews of ideas for studies that can be carried out for Snowmass 2021.*
    - *Present plans for and use of letters of intents and contributed papers within the EF group, and the strategy for MC production.*
- **EF Workshop: July 9-10, 2020** (two full days)
  - First opportunity for the community to present ideas, plans, and results if already available.
  - Plans to have dedicated joint sessions with other Frontiers, and common session between TGs.

Meetings & Calendar

- **Meetings agendas** are on Indico at the link for Energy Frontier
  - *Upcoming Workshops:*
    - Kick-off EF Workshop: Thursday May 21, 2020 (full day)
    - EF Workshop: July 9-10, 2020 (two full days)
- Energy Frontier Meeting Calendar:



Available through EW wiki: **https://snowmass21.org/energy/start**

Direct link:
https://calendar.google.com/calendar/embed?src=brown.edu_njuueqjsrlu8qgdulatqrrmtj4%40group.calendar.google.com&ctz=America%2FNew_York

We hope you will enjoy this kick-off meeting

and

join the work of the Snowmass 2021 Energy Frontier!

Backup slides

“Letters of Interest” and “Contributed Papers”

- **Letters of Interest (LOI)**

  (submission period: April 1, 2020 – August 31, 2020)

  “They allow Snowmass conveners to see what proposals to expect and to encourage the community to begin studying them. They will help conveners to prepare the Snowmass Planning Meeting that will take place on November 4 - 6, 2020 at Fermilab. Letters should give brief descriptions of the proposal and cite the relevant papers to study. Instructions for submitting letters are available at https://snowmass21.org/loi.
  Authors of the letters are encouraged to submit a full write-up for their work as a contributed paper.”

  - ➔ Very brief (two pages).
  - ➔ Uploaded by Authors through Snowmass 2021 Wiki.
  - ➔ Index of submitted LOI available on the Snowmass 2021 Wiki.
  - ➔ Could represent existing work (cite) or new ideas.
  - ➔ Will help the EF conveners plan the work of the Frontier (including liaisons with other Frontiers: avoid duplication/build synergy).
  - ➔ If further developed in the context of the Snowmass 2021 exercise could lead to a Contributed Paper.

“Letters of Interest” and “Contributed Papers”

- **Contributed Papers**

  (submission period: April 1, 2020 – July 31, 2021)

  “Contributed papers will be part of the Snowmass proceedings. They may include white papers on specific scientific areas, technical articles presenting new results on relevant physics topics, and reasoned expressions of physics priorities, including those related to community involvement. These papers and discussions throughout the Snowmass process will help shape the long-term strategy of particle physics in the U.S. Contributed papers will remain part of the permanent record of Snowmass 2021. Instructions for submitting contributed papers are available at https://snowmass21.org/submissions/”

  ➔ More extensive studies.
  ➔ May include white papers, scientific/technical articles, etc.
  ➔ Can but do not have to be related to a given LOI.
  ➔ Submitted by Authors following instructions given on Snowmass 2021 Wiki page (submit to arXiv, send email to M. Peskin with subject “Contribution to Snowmass 2021”, etc.)
  ➔ Will be part of the official Snowmass 2021 records..

Inputs from Collaborations

- **We have started receiving inputs from International Collaborations**
  - Plans for analyses, MC samples, framework availability and how to share them with the Snowmass community, contact people etc.
  - Letters of Interests
- **Following slides show three contributions received so far, more are expected from other collaborations**
- Those contributions will be made available to the whole Snowmass community soon

Inputs from Collaborations: ILC

Opportunities for joining ILC studies at Snowmass 2021

Jim Brau, Jenny List, Michael Peskin, Andrew White

for the LCC Physics and Detector Exec. Board

May 12, 2020

Inputs from Collaborations: ILC

https://indico.cern.ch/event/896263/

How to get involved with ILC

- **Associate Director for Physics and Detectors of the Linear Collider Collaboration (LCC):** Jim Brau jimbrau@uoregon.edu
- **LCC Physics WG: Phenomenology, global interpretations, general physics case, etc**
  - **Coordinators:** Michael Peskin mpeskin@slac.stanford.edu
    Christophe Grojean Christophe.grojean@desy.de
    Keisuke Fujii keisuke.fujii@kek.jp
- **ILD and SiD: Design and optimisation of detector concepts, individual physics analyses, access to large MC data sets**
  - ILD: Spokesperson: Ties Behnke ties.behnke@desy.de
    Physics Coordination: Keisuke Fujii keisuke.fujii@kek.jp
    Jenny List jenny.list@desy.de
    Executive Team member from the US: Graham Wilson gwwilson@ku.edu
  - SiD: Spokespersons: Andy White awhite@uta.edu
    Marcel Stanitzki marcel.stanitzki@desy.de
    Physics Coordination: Tim Barklow timb@slac.stanford.edu
- **Detector R&D, across detector concepts and across collider projects:**
  - CALICE: Roman Poeschl poeschl@lal.in2p3.fr (spokesperson) - Highly granular EM and hadronic calorimetry
  - FCal: Wolfgang Lohmann wolfgang.lohmann@desy.de (spokesperson) - Forward and luminosity calorimetry
  - LCTPC: Allain Bellerive alainb@physics.carleton.ca (regional coordinator for the Americas) - Gaseous tracking
  - Silicon tracking and EM calorimetry : Marty Breidenbach mib@slac.stanford.edu
- **The LCC Physics and Detector group intends to make available signal and background event samples.**

Inputs from Collaborations: ILC

We envision 4 levels of participation:

Fast simulation: A fast-simulation framework and large samples of SM events at ECM = 250, 350, 500, and 1000 GeV. We are compiling a list of study questions covering all aspects of ILC physics.

Full simulation: Corresponding full simulation data in a high-level analysis format that can be used directly in root.

Detailed detector: For detailed detector design, one should learn the ILCSoft simulation framework. The SiD and ILD groups will offer no-cost guest memberships.

Detector R&D: A comprehensive list of current R&D projects is available; scan this list for potential collaborators. The R&D collaborations invite new members.

Inputs from Collaborations: ILC

We are preparing a list of questions for possible Snowmass analyses, with references to existing work. At the moment, we have about 50 questions, in a 20-page document. Some examples:

Higgs #4

4. Higgs decays to 2 jets. At lepton colliders, Higgs decays to all hadronic modes can be observed directly. Current studies of $h \to b\bar{b}, gg, c\bar{c}$ date from the era before deep learning, and before the understanding of q/g jet separation gained from LHC. What, now, is the optimum method for separating these three decay modes. What systematic errors can be achieved?

2-fermion #4

4. $e^+e^- \to \tau^+\tau^-$. The tau lepton has a unique role in studies of e^+e^- 2-fermion production because its polarization can be directly measured. How can we best use this additional handle to constrain or discover BSM models?

We expect to have these questions and simulation resources available in the next month or so, to help Snowmass participants begin hands-on study of ILC physics.

Inputs from Collaborations: FCC

MEMORANDUM

From: FCC Physics and Experiments Design Study; M. Benedikt, A. Blondel, P. Janot, M. Mangano
To: Snowmass conveners
Object: Participation to the 2020-2021 Snowmass Study

Contact persons

The contact persons from the FCC physics and experiments studies to the Snowmass study frontiers are as follows:

- Overall contact: Markus Klute, plus Alain Blondel, Patrick Janot and Michelangelo Mangano
- Energy Frontier: Patrizia Azzi and Gregorio Bernardi (FCC-ee), Michele Selvaggi (FCC-hh), Christophe Grojean (Phenomenology)
- Frontiers in Rare Processes and Precision Measurements: Stéphane Monteil (b and c physics) and Mogens Dam (τ physics)
- Theory Frontier: Matthew McCullough
- Instrumentation Frontier: Mogens Dam and Franco Bedeschi
- Computational Frontier: Luc Poggioli

Software support can be obtained from the FCC software group (see C. Helsens and G. Ganis in [14]) who will be happy to integrate software contributions.

Inputs from Collaborations: FCC-hh

CERN-FCC-PHYS-2020-0005
12 May 2020

A framework and goals for FCC-hh physics studies at Snowmass 2021

Clement Helsens[1)]*, Michelangelo L. Mangano[2)]*, Michele Selvaggi[3)]*

* *European Organization for Nuclear Research (CERN), Geneva, Switzerland*

Abstract

We summarize the key results obtained by physics studies carried out for the FCC-hh Conceptual Design Report, documenting the existing tools and software framework that were developed. Indications are provided for further work, on physics performance and simulation software development, which could be a target for Snowmass 2021 studies of a pp collider at 100 TeV. The primary goal of this note is to inform about, and document, the existing resources, to encourage coordination and collaboration building on the work already done.

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[2] michelangelo.mangano@cern.ch
[3] michele.selvaggi@cern.ch

Contents

Input from Collaborations: LHeC

CERN-ACC-NOTE-2018-0084
December 18, 2018

Exploring the Energy Frontier with Deep Inelastic Scattering at the LHC

A Contribution to the Update of the European Strategy on Particle Physics

LHeC and PERLE Collaboration

Contacts: Oliver Brüning (CERN) and Max Klein (U Liverpool)
oliver.bruning@cern.ch, max.klein@liverpool.ac.uk

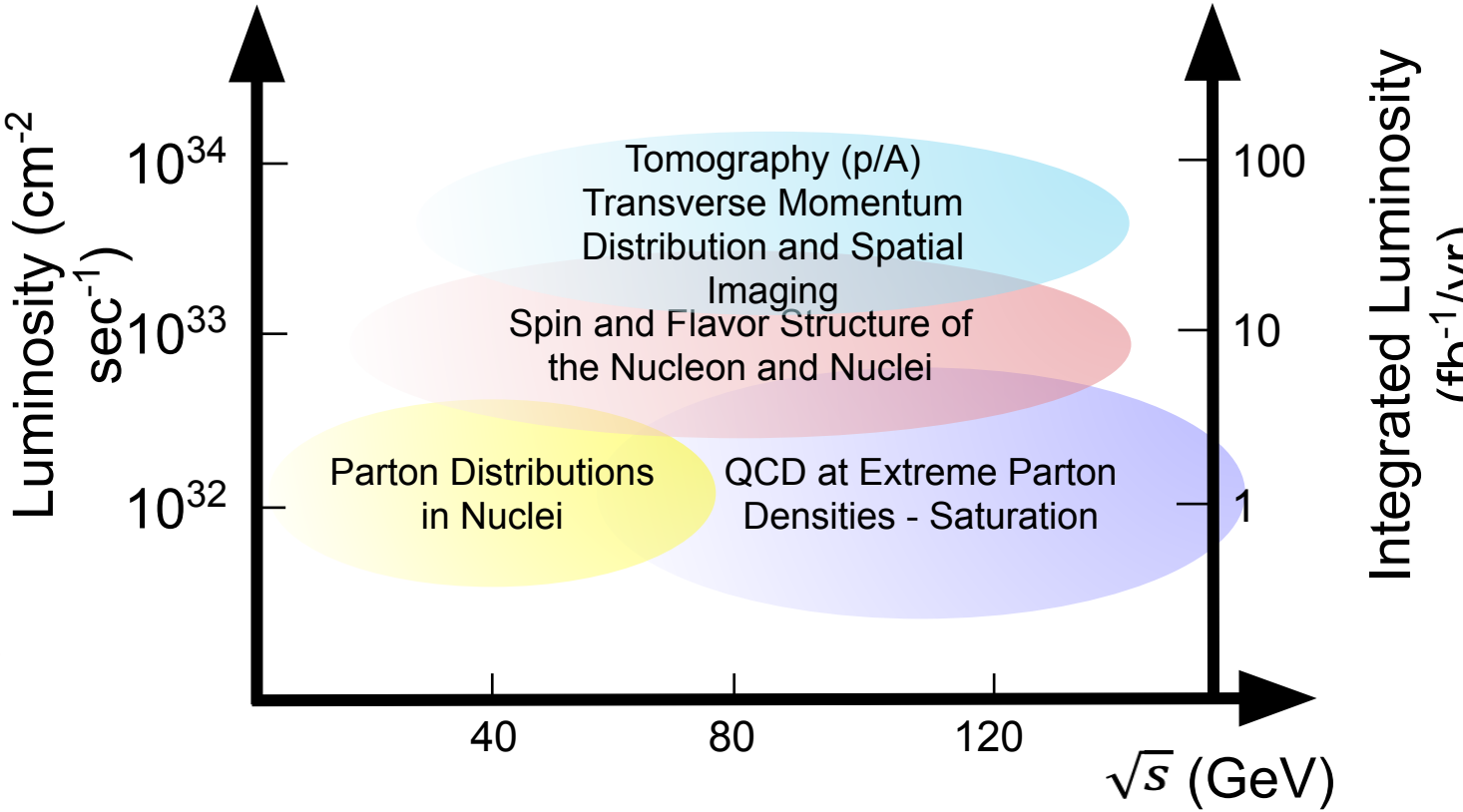
Executive Summary

The Large Hadron Collider determines the energy frontier of experimental collider physics for the next two decades. Following the current luminosity upgrade, the LHC can be further upgraded with a high energy, intense electron beam such that it becomes a twin-collider facility, in which ep operates concurrently with pp. A joint ECFA, CERN and NuPECC initiative led to a detailed conceptual design report (CDR) [1] for the Large Hadron Electron Collider (LHeC) published in 2012. The LHeC uses a novel, energy recovery linear (ERL) electron accelerator which enables TeV energy electron-proton collisions at high luminosity, exceeding that of HERA by nearly three orders of magnitude. The discovery of the Higgs boson and the surprising absence of BSM physics at LHC demand to extend the experimental base of particle physics suitable to explore the energy frontier, beyond pp collisions at the LHC. Following a mandate of the CERN Directorates and guided by an International Advisory Committee, this motivated representatives of more than 100 institutes to proceed, as sketched here, with the development of the accelerator, physics and detector prospects for the LHeC with the intention to publish an update of the CDR in early 2019 [2].

The very high luminosity and the substantial extension of the kinematic range in deep inelastic scattering (DIS) compared to HERA, make the LHeC a uniquely powerful TeV energy collider, which rests on a maximal exploitation of the LHC infrastructure. Realising an "Electrons for LHC" [3] programme would create the cleanest, high resolution microscope accessible to the world, one may term a "CERN Hubble Telescope for the Micro-Universe". It is directed to unravel the substructure of matter encoded in the complex dynamics of the strong interaction, a necessary input for future hadron colliders, including HL-LHC. Being complementary to the LHC and a possible future e^+e^- machine, the LHeC would scrutinise the Standard Model (SM) deeper than ever before, and possibly discover new physics in the electroweak and chromodynamic sectors. Adding ep transforms the LHC into an outstanding, high precision Higgs facility. Through the extension of the kinematic range by about three orders of magnitude in lepton-nucleus (eA) scattering, the LHeC is the most powerful electron-ion research facility one can build in the next decades, for elucidating the chromodynamic origin of the Quark-Gluon-Plasma and clarifying the partonic substructure and dynamics inside nuclei for the first time.

Input from Collaborations: EIC

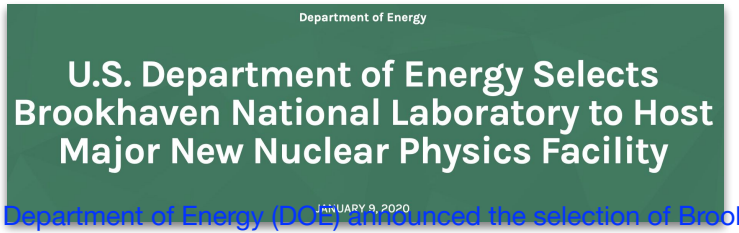
- EIC: Study structure and dynamics of matter at high luminosity, high energy with polarized beams and wide range of nuclei



EIC CD0 and Site Selection

- Announcement by the Department of Energy on January 9, 2020

https://www.energy.gov/articles/us-department-energy-selects-brookhaven-national-laboratory-host-major-new-nuclear-physics



WASHINGTON, D.C. – Today, the U.S. Department of Energy (DOE) announced the selection of Brookhaven National Laboratory in Upton, NY, as the site for a planned major new nuclear physics research facility. The Electron Ion Collider (EIC), to be designed and constructed over ten years at an estimated cost between $1.6 and $2.6 billion, will smash electrons into protons and heavier atomic nuclei in an effort to penetrate the mysteries of the "strong force" that binds the atomic nucleus together.

The EIC's high luminosity and highly polarized beams will push the frontiers of particle accelerator science and technology and provide unprecedented insights into the building blocks and forces that hold atomic nuclei together. Design and construction of an EIC was recommended by the National Research Council of the National Academies of Science, noting that such a facility "would maintain U.S. leadership in nuclear physics" and "help to maintain scientific leadership more broadly." Plans for an EIC were also endorsed by the federal Nuclear Science Advisory Committee.

Secretary Brouillette approved Critical Decision-0, "Approve Mission Need," for the EIC on December 19, 2019. "The Department is excited to be moving forward with an Electron Ion Collider at Brookhaven National Laboratory," stated **Office of Science Director Dr. Chris Fall**. "However, participation from many parts of the DOE laboratory complex will be essential if the EIC is to be a success."
Thomas Jefferson National Accelerator Facility in Newport News, VA will be a major partner in realizing the EIC, and several other DOE laboratories are expected to contribute to EIC construction and to the groundbreaking nuclear physics research program that will be accomplished there.

Engagement in SnowMass2021 process

- EIC program provides excellent opportunities for HEP community such as QCD and electro-weak physics in addition to novel instrumentation applications.
- The EIC User group is committed through the EICUG Steering Committee to engage in the process of formulating Letters of Interest for various working groups including EF04, EF05, EG06 and EF07, besides Instrumentation Working Groups. Several informal discussions took place between the EICUG Steering Committee and several co-conveners.
- The EICUG Steering Committee is committed to help this process to ensure that EIC-related submissions are consistent with the overall EIC planning of a new collider facility in the US at Brookhaven National Laboratory in cooperation with the DOE Office of Nuclear Physics.